



University of Pennsylvania
ScholarlyCommons

Marketing Papers

Wharton Faculty Research

12-2005

Theory-Driven Choice Models

Tülin Erdem

Kannan Srinivasan

Wilfred Amaldoss

Patrick Bajari

Hai Che

See next page for additional authors

Follow this and additional works at: http://repository.upenn.edu/marketing_papers

 Part of the [Marketing Commons](#)

Recommended Citation

Erdem, T., Srinivasan, K., Amaldoss, W., Bajari, P., Che, H., Ho, T., Hutchinson, W., Katz, M., Keane, M., Meyer, R., & Reiss, P. (2005). Theory-Driven Choice Models. *Marketing Letters*, 16 (3/4), 225-237. <http://dx.doi.org/10.1007/s11002-005-5887-z>

This paper is posted at ScholarlyCommons. http://repository.upenn.edu/marketing_papers/190
For more information, please contact repository@pobox.upenn.edu.

Theory-Driven Choice Models

Abstract

We explore issues in theory-driven choice modeling by focusing on partial-equilibrium models of dynamic structural demand with forward-looking decision-makers, full equilibrium models that integrate the supply side, integration of bounded rationality in dynamic structural models of choice and public policy implications of these models.

Keywords

dynamic choice, structural modeling and estimation, heuristics and biases

Disciplines

Business | Marketing

Author(s)

Tülin Erdem, Kannan Srinivasan, Wilfred Amaldoss, Patrick Bajari, Hai Che, Teck Ho, Wesley Hutchinson, Michael Katz, Michael Keane, Robert Meyer, and Peter Reiss

Theory-Driven Choice Models

Tülin Erdem, Kannan Srinivasan, Wilfred Amaldoss, Patrick Bajari, Hai Che, Teck Ho, Wes Hutchinson, Michael Katz, Michael Keane, Robert Meyer, and Peter Reiss.

Abstract

We explore issues in theory-driven choice modeling by focusing on partial-equilibrium models of dynamic structural demand with forward-looking decision-makers, full equilibrium models that integrate the supply side, integration of bounded rationality in dynamic structural models of choice and public policy implications of these models.

Key Words: Dynamic Choice, Structural Modeling and Estimation, Heuristics and Biases

There are at least three reasons to care about choice and decision making: (a) knowledge for its own sake (i.e., explaining choice processes); (b) the design of business strategy and tactics; and (c) the design of public policy. The goal of the theory-driven approach is to generate more accurate and useful models of choice for all three purposes.

There has been considerable debate about what constitutes a “theory-driven” or “structural” model. The underlying distinction is worth exploring, if not obsessing over. The question of whether an empirical model is “theory driven” versus “data driven” comes down to whether the econometric specification is derived from theory. Theory is valuable to the extent it imposes a priori restrictions (from economics or marketing) on the statistical relationships to be estimated. Choice modelers have adopted three general approaches to developing theory-driven choice models. One approach is to use the rational-actor model of economics, which assumes that decision makers maximize profits or utility, to derive decision rules for actors. A second approach uses psychological decision-making theories to predict choice behavior. A somewhat less often used third approach is to take as given empirical regularities observed in other data (e.g., the tendency of decision makers to put excessive weight on low probability events).

Reiss and Wolak (2002) define a structural model as “Any model that provides a behavioral interpretation for some or all of the parameters.” Since this definition is a rather broad one, emphasizing the implications of this definition helps us to set some boundaries:

- (1.) *Explicit specification:* The econometric specification builds on a stated theoretical model of choice and decision making and involves explicit specification of the underlying behavioral processes.
- (2.) *Policy Invariance:* The parameters estimated are invariant to policy changes (Lucas 1976). This is essential if the choice model is to be used for prediction or generating counterfactuals.
- (3.) *Structural vs. Reduced-form Modeling:* There are at least two meanings of *reduced form*. The classical meaning is that one uses a fully specified theoretical model to derive specific predictions for data relationships. Data are then analyzed to see if they fit those relationships, without reference to the full model or system (for example, if lagged choices matter and one specifies a utility function with lagged purchases without specifying the process by which past choices affect current choices, this would be a reduced-form model in the classical sense). A more recent, and somewhat more colloquial, use of the term is to refer to a data-driven approach under which one fits a purely statistical model (such as the negative binomial distribution (NBD) model) to data without first developing an underlying theoretical model (such as one based on random utility maximization).

This paper surveys several of the leading issues in theory-driven modeling of choice. In each area, we identify some of the leading contributions. We focus is on five themes:

- (1) *Dynamic demand models with forward-looking agents.* Consumers often make forward-looking choices in dynamic settings. Ignoring such behavior can lead to misleading conclusions (Section I).
- (2) *Supply-side choices.* The supply side matters for two reasons. One, it is of interest in itself. Two, misspecification of the supply side can contaminate the estimates of demand-side parameters. (Section II).
- (3) *Boundedly rational decision-makers.* Boundedly rational decision-makers may employ simplifying decision heuristics. Provided that these heuristics are stable, it may be possible to integrate these into current models (Section III).
- (4) *Computation costs.* Theory-driven models may provide benefits in terms of improved parameter estimates and behavioral predictions, but they also impose a high computational cost. Recent work in structural estimation aims to decrease this cost (Section IV).

(5) *Public policy.* We explore the role of choice models in public policy. We identify some of the central policy issues driven by both traditional economic approaches to choice modeling and by more recent behavioral approaches (Section V).

The paper closes with a very brief look toward future issues.

I. THE DEMAND SIDE: DYNAMIC STRUCTURAL MODELS OF CHOICE WITH FORWARD-LOOKING AGENTS

In this paper, we focus on dynamic structural models of choice with forward-looking decision-makers. These models specify the consumer's utility function with the explicit recognition of inter-temporal dynamics. Several papers in marketing and economics have investigated consumer learning about quality of alternative brands of an experience good. In these models, consumers are forward-looking in that they take into account how information from today's purchases affects the expected future utility of subsequent purchases (e.g., Erdem and Keane 1996, Anand and Shachar 2002, Akerberg 2003). Several of these papers also incorporate advertising as a source of information and investigate the role it plays in consumer choices. Finally, Mehta, Rajiv and Srinivasan (2004) incorporated consumer forgetting into models strategic product trial behavior.

Several papers have modeled consumer search utilizing dynamic structural choice models. Mehta, Rajiv and Srinivasan (2003) estimate a dynamic structural consideration set formation and brand choice model when (price) search is costly. One of their main findings is that while in-store display activities and feature ads do not influence consumers' quality perceptions of the brands, they increase the probability of the brands being considered by reducing search costs. Erdem, Keane, ü and Strebel (2004) investigate consumer information search and choice behavior in high-tech durables. They estimate a dynamic structural model where consumers make sequential decisions about how much information to gather prior to making a PC purchase.

Finally, consumers' may not only have quality expectations and update these based on new information but they may form price expectations as well. In frequently purchased product

categories, prices often fluctuate around a mean due price promotions (e.g., price cut or couponing). Gönül and Srinivasan (1996) examine the impact of consumer expectations of availability of coupons in the future on consumer choice behavior. Sun, Neslin and Srinivasan (2003) compare a structural model with expectations about future promotions and a number of reduced-form models. The comparisons reveal that the reduced form models that ignore such forward-looking behavior substantially overestimate switching probabilities. Erdem, Imai and Keane (2003) and Hendel and Nevo (2003) model explicitly future price expectations and investigate the impact on when, what and how much to buy. Both papers conclude that future price expectations have a large impact on choices.

Price expectations play an important role in consumer choice in durables, especially high-tech consumer durables, as well. A key feature of high-tech durables markets is the tendency for prices to fall quickly over time, creating an incentive to delay purchases. Melnikov (2000) models consumer behavior in this context using data from the computer printer market. Song and Chintagunta (2003) analyze the impact of price expectations on the diffusion patterns of new high-technology products using aggregate data. Erdem, Keane, Öncü and Strebel (2004) model information search, purchase incidence and PC choice when consumers both learn about quality and form expectations about price drops. A key finding about price expectations in their paper is that estimates of dynamic price elasticities of demand exceed estimates that ignore the expectations effect by roughly 50%.

There is ample empirical evidence that decision-makers can be forward-looking and ignoring such behavior when present may lead to misleading conclusions. However, there are also many challenges ahead. First, these models take the supply side of the market as given (see Section II), which may lead to “endogeneity” issues (since firm-consumer interactions are not modeled). Furthermore, possible correlations between observed (e.g., price) and unobserved variables (e.g., consumer inventory) in the demand equation may lead to omitted variables problem (this is so even

if prices are exogenous to consumers but this problem is also often referred to as endogeneity problem as well). For example, Erdem, Imai and Keane (2003) show that when consumer stockpiling and consumer future price expectations are present, models that ignore this type of dynamics create “endogeneity” problems since inventories are correlated with prices and ignoring inventories create an omitted variables problem (and this is true even if in this context prices are exogenous to individual consumers, for which Erdem, Imai and Keane (2003) find empirical evidence).

Second, most of the papers in this area assume decision-makers to have rational expectations for tractability reasons. However, the objective functions can be specified in a way to allow for boundedly rational behavior (Section III discusses some possibilities in that context). In these settings, empirical identification will be a challenge. One way to alleviate identification problems would be to use multiple data sources (such as transactional data on purchases along with data on decision-makers’ expectations (e.g., Erdem, Keane, Öncü and Strebel 2004)). This would enable researchers to relax some of the restrictive behavioral assumptions commonly employed in these models. Finally, behaviorally richer models pose computational challenges. Recent work on two-step methods (see Section IV) can alleviate some of these challenges.

II. THE SUPPLY SIDE: STRUCTURAL MODELS OF FIRM CHOICES

There are two broad reasons to consider supply-side choice (firms’ decisions). First reason is to understand the nature of interactions among firms and competition. Second, ignoring the supply side may lead to biased demand parameter estimates due to potential endogeneity problems. Suppose, for example, that a supplier targets consumers based on their likely willingness to pay, with the result that consumers with higher demands are charged higher prices. An econometrician using cross-sectional data and assuming that prices randomly vary might well fit an upward sloping demand curve to the resulting purchase data. The problem is that, although prices are exogenous

from the perspective of any given consumer, they are endogenous from the perspective of the overall system of supply and demand.

Given sufficient data, researchers ideally would specify a complete system of supply and demand equations. Often, however, marketing researchers lack important information about the supply side, such as costs or variables that affect costs. Industrial organization economists have developed strategies for deriving estimates of costs from the first-order conditions for profit maximization. To illustrate the logic of this process, consider how one might recover a monopolist's unknown constant marginal cost of production. Suppose that the firm sets a single, uniform price, p . The well-known Lerner equation implies that a profit-maximizing monopolist will operate at a point where $\frac{p - c}{p} = \frac{-1}{\eta}$, where η is the elasticity of demand and c is the marginal cost. Thus, one can estimate c if one has data on p and an estimate of η .

This simple monopoly example suggests how we might proceed in more complicated competitive marketing settings. Two notes of caution are in order, however. First, if one is using this approach to advise managers, why not approach the firm directly to get access to cost data? If the answer is that the firm lacks the data, then one must question whether the estimates derived by the technique above are meaningful. The answer to that question will depend on how the firm sets its prices in the absence of such data. Second, there are many complications that arise in actual applications, not the least of which are that firms: (1) sell multiple related products; (2) face strategic competitors; (3) are part of vertical distribution channels; (4) face inventory costs and demand and supply uncertainty; (5) may bundle or otherwise change product attributes; (6) make dynamic production and pricing decisions; and (7) may have reasons to change prices infrequently or irregularly. Each of these issues poses important conceptual and practical issues that have received recent attention in the marketing and industrial organization literatures.

One important initial issue is how to specify the objectives of retailers and manufacturers. While the assumption of profit maximizing behavior is fairly standard, there is less agreement about how to model the frequency with which firms change prices and promote, the extent to which prices should vary across regions and products (e.g., Chintagunta et al. (2003) and Draganska and Jain (2004)) and expectations about competitors' objectives. Regarding the latter, there are important issues about how to model interrelations between the profitabilities of different products in a line and across product families. Sudhir (2001) is one example of a study that considers alternative objectives (e.g., category profit maximization, brand profit maximization, and choosing a constant markup).

A second area of concern is modeling the rich nature of vertical relationships between manufacturers, wholesalers and retailers. Berto Vilas-Boas (2002) and Vilas-Boas and Zhao (2004) use independent manufacturer-dealer models to recover simultaneously estimates of manufacturers' and retailers' unobserved costs and competitive pricing behavior. Due to data limitations, analysis of more complex contracts between manufacturers and dealers (e.g., slotting allowances, nonlinear tariffs) await development. Furthermore, most empirical marketing and economic models assume product offerings and product attributes are fixed, including retailer attributes. Such assumptions are likely reasonable assumptions in the short run. Some progress has been made in modeling longer run changes in location or quality (e.g., Reiss, 1996) but much remains to be done (Berry and Reiss, 2004).

To date, there has been less progress in modeling dynamic supply issues, largely because dynamic models raise complex game-theoretic, learning, and channel issues. Nevertheless, progress continues to be made. Che, Seetharaman and Sudhir (2004) study firms' intertemporal pricing behavior when consumer choices are state-dependent. Aguirregabiria (1999) studies the interaction

of inventory and price decisions in retailing firms, and allows for stock-out occasions to influence prices.

The presence of strategic competitors requires changing the first-order condition above to take into account firms' equilibrium predictions of competitor behavior. The most common approach is to assume that firms are Bertrand-Nash competitors. There is, however, evidence suggesting this may not be a reasonable assumption (e.g., McKelvey and Palfrey 1995). This has led some to explore alternative game-theoretic models, such as Stackleberg, perfectly collusive, and Cournot-Nash. Previous work has attempted to estimate so-called conjectural variation parameters and interpret them as behavioral parameters but Reiss and Wolak (2003) discuss problems with such interpretations. These problems include that: equilibrium outcomes do not necessarily reveal what firms would do in response to competitors' actions; most estimated parameters do not have an obvious behavioral interpretation, and conjectural parameters, like costs estimates, can be very sensitive to minor changes in functional form and distributional assumptions.

III. INCORPORATING BOUNDED RATIONALITY IN STRUCTURAL MODELS OF CHOICE

Dynamic structural models of choice assume a high degree of consumer sophistication; consumers are assumed to plan over long horizons, have stable preference structures, and, most importantly, make decisions in the short run that optimize long-run utility. Research in economics, marketing and psychology, however, has long offered a quite different view of how decisions are actually made; consumers more often appear myopic, inconsistent, and make decisions that strongly depart from those prescribed by theories of rational choice. One of the major future challenges of structural models is develop forms that offer a more realistic portrait of how decisions are actually made. For example, one assumption of traditional dynamic-structural models that is often called into question is that consumers are efficient forward planners. That is, they consider the consequences of their current decisions over long time horizons, and take these consequences

optimally into account when making short-run decisions. There is extensive evidence from the study of both games and dynamic decision problems, however, that not only do people fail to engage in the backward-inductive reasoning required by many multi-period optimizations, but that forward-reasoning is also often quite limited—typically not more than one or two periods ahead (e.g., Camerer *et. al.* 2004; Meyer and Shi 1995). Fortunately, this is the easiest limitation to capture in dynamic models; by optimizing over increasingly limited horizons analysts can let the data decide the forward-planning ability that appears to best describes consumers’ and firms’ choices.

A closely-related limitation is that dynamic models commonly adopt an extremely simple assumption about how consumers discount the future when making decisions over time—that of constant discounting. Empirical research, however, has consistently shown that intuitive discounting is better captured by a quasi-hyperbolic discount function of the form $\{1, \beta, \beta\delta, \beta\delta^2, \beta\delta^3, \dots\}$ where $\beta < 1$ (e.g., Laibson (1997; Lowenstein and Prelec 1992). This discounting function has been shown to account for behavior such as procrastination, addiction and job search (see O’Donoghue and Rabin 1999).

A third area of behavioral concern is the treatment of learning. Typically, decision makers are assumed to take in observations about the world and update beliefs by applying Bayes’ rule. An active area of research in both economics and psychology has been to develop models that offer a more accurate description of how individuals actually learn in complex dynamic environments and games. Developments in this area have been extensive, and include the Experience-Weighted attraction (EWA) learning model of learning proposed in economics by Camerer and Ho (1999), and cognitive-process models of learning proposed in psychology by (e.g., Busemeyer and Myung 1992 and Kruschke 1992). One important insight that has emerged from this work is the finding that highly-sophisticated patterns of behavior can emerge from quite simple assumptions about how people learn. For example, March (1996) reports simulation results where the dynamics of learning

(based on several classic models of animal learning) induce risk averse and loss averse behavior, despite the assumption of a linear utility function.

A final area of concern is the near-universal assumption of dynamic structural models is that utility functions are contextually and temporally invariant. That is, the utility a consumer realizes from a good is modeled as being independent of the features of the set from which it was chosen and the historical sequence of choices that preceded it. There is ample empirical evidence, however, that this assumption is commonly violated, such as the tendency of decision makers tend to evaluate options relative to points of reference, and strongly prefer avoiding losses to acquiring gains (Kahneman and Tversky, 1979).

Although a large number of proposals for capturing such effects in static choice models have appeared (for example, representing attribute values as positive and negative departures from choice-set means or historical norms; Kahneman and Tversky 1979; Tversky and Simonson 1993), less work has focused on how best to incorporate such effects in dynamic models. One barrier has been computational complexity; estimating a model that allows preferences to be contingent on the features of current and previous choice sets requires optimization over an extremely large state space, something that may be infeasible in most applied problems. Second, even if estimation is possible, little is known about the degree to which classic context effects extend to tasks where consumers have the goal to maximize the utility gained from a *series* of decisions rather than just one. It is unlikely, for example, that the same aversion for extreme tradeoffs would apply to settings where decision makers anticipate making a series of such choices (hence smoothing risk) and can learn from their experienced utility.

V. REDUCING THE COMPUTATIONAL BURDEN OF STRUCTURAL ESTIMATION

Estimating structural models can be computationally difficult. For example, dynamic discrete choice models are commonly estimated using the nested fixed point algorithm (see Rust

1994). This requires solving a dynamic programming problem (DP) thousands of times during estimation and numerically maximizing a nonlinear likelihood function. To make estimation practical in all but the most simple models, it is therefore necessary to use rather fast approximate solutions to the DP problem rather than using exact solutions. Geweke and Keane (2001) develop methods for quasi-structural estimation in which structural parameters can be estimated without fully actually solving the DP problem. The idea is to treat the future component of agents value functions as flexible reduced-form functions that can be estimated jointly with the structural parameters of current payoff functions. Recently, Houser, Keane and McCabe (2004) applied this approach to experimental data to learn about how subjects form expectations.

Estimation problems in equilibrium models can be at least as computationally challenging. In the remainder of this section, we discuss some recent research that proposes computationally simple estimators for structural models including auctions, demand in differentiated product markets, dynamic discrete choice and dynamic games. The estimators we discuss use a two-step approach. In the first step, one flexibly estimates a reduced form for agents' behavior consistent with the underlying structural model. In the second step, the one recovers the structural parameters, by plugging the first-step estimates into the model. A simple auction game illustrates the approach:

Consider a first-price sealed-bid auction with $i=1,...,N$ bidders, who have independent private values. Bidder i 's valuation, v_i is private information and is an i.i.d. draw from a distribution F . Let $\pi(b_i; v_i)$ denote bidder i 's expected utility when her bid is b_i . If bidder i is risk neutral, then

$$\pi(b_i; v_i) = (v_i - b_i) G(b_i)^{N-1} \quad (1)$$

In (1), $G(b)$ denotes the equilibrium distribution of bids. The term $G(b_i)^{N-1}$ is the probability that i wins the auction, i.e. that the other $N-1$ bidders bid less than b_i . Conditional on winning, i 's utility is

her valuation minus her bid, $v_i - b_i$. Bidder i 's expected utility is therefore her surplus conditional on winning, $v_i - b_i$, times the probability that i wins, $G(b_i)^{N-1}$.

The first order condition with respect to b_i is:

$$-G(b_i)^{N-1} + (N-1)(v_i - b_i)G(b_i)^{N-2}g(b_i) = 0, \quad (2)$$

or

$$v_i = b_i + \frac{G(b_i)}{g(b_i)(N-1)}. \quad (3)$$

In a structural auction model, the goal of estimation is to learn F , the distribution of the bidders' private valuations. Guerre, Perrigne and Vuong (2000) proposed a computationally simple estimator based on (3). Notice that all of the right hand side variables can either be directly observed (e.g., the bid b_i) or can be estimated from the data (such as G and g). This allows the economist to recover an estimate of v_i by evaluating the empirical analogue of (3).

There are three steps in this approach. Suppose that the econometrician observes $t=1, \dots, T$ repetitions of the auction. Let $b_{i,t}$ denote the bid that i submits in auction t . First, use nonparametric methods generate estimates \hat{G} and \hat{g} of G and g . Given the bids $\{b_{i,t}\}_{i=1, \dots, I, t=1, \dots, T}$, an estimate \hat{g} of g could be formed using kernel density estimation. A nonparametric estimate \hat{G} of G can also be formed using standard methods. Given the first-step estimates \hat{g} and \hat{G} , in a second step we estimate bidder i 's valuation in auction t as:

$$\hat{v}_{i,t} = b_{i,t} + \frac{\hat{G}(b_{i,t})}{\hat{g}(b_{i,t})(N-1)} \quad (4)$$

By applying equation (4) to every bid in the data, we can generate estimates, $\{\hat{v}_{i,t}\}_{i=1, \dots, I, t=1, \dots, T}$, of the valuations associated with each bid in our data set. A third step is to estimate F as the cdf of the $\{\hat{v}_{i,t}\}_{i=1, \dots, I, t=1, \dots, T}$. An advantage of this estimator is that it is simple to

compute and imposes minimal parametric assumptions. Bajari and Hortacsu (2003) were able to code a version of this estimator using just a few lines of STATA.

The key insight of Guerre, Perrigne and Vuong was that the first-order conditions (3) can be expressed as private information on the left-hand side and as functions of the bids on the right hand side. By observing a large number of repetitions of the auction, one can recover all of the right hand side variables. This identifies the private information v_i . Table 1 below gives examples of papers that utilized two-step estimators.

Table 1: Two-Step Estimators for Structural Models in the Literature

| Class of Models | Papers |
|---|--|
| Auctions | Guerre, Perrigne, Vuong (2000), Bajari and Hortacsu (2003), Bajari and Ye (2003) |
| Demand in a differentiated product market | Petrin and Train (2003), Bajari and Benkard (2003) |
| Dynamic Discrete Choice | Hotz and Miller (1993), Aguirregabiria and Mira(2002) |
| Dynamic Games | Pakes, Ostrovsky and Berry (2003), Pesendorfer and Schmidt-Dengler (2003) |

The two-step estimators can have also drawbacks. First, there can be a loss of efficiency. The parameters estimated in the second step will depend on a nonparametric first step. If this first step is imprecise, the second step will be poorly estimated. Second, stronger assumptions about unobserved state variables may be required. In a dynamic discrete choice model, accounting for unobserved heterogeneity by using random effects or even a serially correlated, unobserved state variable may be possible using a nested fixed point approach. However, two-step approaches are computationally light, often require minimal parametric assumptions and are likely to make structural models accessible to a larger set of researchers.

V. PUBLIC POLICY IMPLICATIONS

Theory-driven choice modeling can contribute to public policy formulation in several ways, but current modeling efforts must address a number of issues before they can be fully useful. We

illustrate these points through application of theory-based choice models to antitrust policy.

Theory-driven choice modeling can potentially improve antitrust analysis in at least two ways.

One is by providing more sophisticated models of rational consumer choice. American antitrust policy is largely based on rational-actor models that are used to form predictions of consumer behavior (often summarized in terms of cross-price elasticities) that are central to the assessment of market power and estimation of the efficiency effects of supplier practices such as product bundling or merger. As discussed in Section I above, dynamic structural models of choice with forward-looking agents (e.g., Erdem, Imai, and Keane (2003)) can lead to dramatically different estimates of consumer responsiveness and brand-switching behavior. Hence, a merger analysis based on elasticities estimated from a model that ignores dynamics may be seriously misleading.

The use of more sophisticated structural models of consumer choice raises a number of issues. In models in which consumers hold inventories, for example, the cross-elasticity of demand associated with a price decrease may be much larger than the elasticity associated with a price increase. And the short-run cross-elasticity associated with a price decrease may be larger than the corresponding long-run elasticity. These possibilities raise an important issue for future research: which elasticities are the correct ones to use in antitrust analysis? Some would argue that long-run elasticities are what matters for welfare calculations, but suppliers may respond to short-run elasticities in determining their optimal dynamic strategies. Fully answering the question of which elasticities to use will require modeling both supplier and buyer behavior simultaneously, and it will raise many of the thorniest issues identified in Section II above.

A second potential contribution of theory-driven choice modeling to antitrust analysis is that it can provide more realistic predictions of buyer and supplier behavior by building on behavioral decision-making models.¹ On the consumer side, for example, one could examine whether

¹ Jolls *et. al.* 1998 address many of the implications of behavioral decision theory for public policy generally.

consumers take life-cycle costs of durable goods into account or are boundedly rational as discussed in Section III above. The answer to such a question might be critical in the assessment of whether certain practices (e.g., tying the purchase of repair parts to the original supplier) create market power.

Behavioral decision making models can also potentially contribute to our understanding of supplier behavior. Consider a vertical merger. Rational-actor models often indicate that a firm acquiring the supplier of a critical input would continue to have incentives to sell that input to rivals who also need it. A behavioral approach, however, might assert that managers have an irrational tendency to exclude rivals and harm competition.

This divergence points out a tension. Proponents of the behavioral approach would assert that it provides greater realism and improves policy. But an important current role of economics is to provide a logical check that limits governmental intervention. There is a danger of using behavioral models that are still at an early stage of development and empirical testing: a wide range of accusations might be supported with little actual evidence, and the discipline provided by rational actor models could be lost. It should also be noted that empirical testing must examine more than whether decision makers initially behave as predicted by the models. One also has to check whether the decision-making processes have lasting consequences for market performance. Suppose, for instance, that—as a result of their bounded rationality—the managers of a vertically merged firm engaged in exclusion but soon found that it was a very unprofitable strategy and abandoned it. If the correction is made quickly enough, one might argue that the effects of bounded rationality and use of trial-and-error could reasonably be approximated by an assumption of rationality. More generally, a fundamental issue is whether market outcomes exhibit the effects of irrationality when some agents are rational.²

² In some settings, competition among rational suppliers may be a “substitute” for consumer rationality. Disclosure policy, such as truth-in-lending laws and mandatory food labeling, provides a good illustration of this issue. The rational-actor model of consumers indicates that, even with a monopoly seller, there will be complete information

VI. GOING FORWARD

There has been a great deal of progress in theory-driven choice modeling. Challenges provide also exciting future research opportunities in this area. A better taxonomy of ordered biases needs to be established and these biases need to be integrated into the objective functions. Integration of multiple and richer data sources can overcome empirical identification issues and may enable researchers to relax some of the behaviorally restrictive assumptions. Finally, broadening the set of applications to settings with important policy implications would be a welcome development.

References

- Akerberg, D. (2003), "Advertising, Learning, and Consumer Choice in Experience Good Markets: *Advances in Economics*, Volume 1, Amsterdam: North Holland.
- Aguirregabiria, V. (2002) "Sales Promotions in Supermarkets: Estimating Their Effects Profits and Consumer Welfare," Boston University working paper.
- Aguirregabiria, V. (1999) "The Dynamics of Markups and Inventories in Retailing Firms," *The Review of Economic Studies*, 66, 275-308.
- Aguirregabiria, V., and P. Mira (2002) "Swapping the Nested Fixed Point Algorithm: A Class of Estimators for Discrete Markov Decision Models," *Econometrica*, 70, 1519-1543.
- Anand, B., and R. Shachar (2002) "Risk Aversion and Apparently Persuasive Advertising." Harvard Business School Working Paper Series, No. 02-099.
- Bajari, P., and L. Ye (2003) "Deciding Between Competition and Collusion," *Review of Economics and Statistics*, 85(4), 971-989.
- Bajari, P. and C.L. Benkard (2003) "Demand Estimation With Heterogeneous Consumers and Unobserved Product Characteristics: A Hedonic Approach," NBER Working Paper w10278.
- Bajari, P., and A. Hortacsu (2003) "Are Structural Estimates of Auction Models Reasonable? Evidence from Experimental Data," NBER Working Paper w9889.
- Baye, M. and J. Morgan, "Price Dispersion in the Lab and on the Internet: Theory and Evidence," *RAND Journal of Economics*, 35(3), 449-466.

disclosure if consumers know what they don't know and are rationally skeptical in that they assume the worst if the supplier does not voluntarily disclose the relevant information (Grossman 1981). This mechanism breaks down if consumers are boundedly rational and don't know what they don't know. But rational competitive firms will have incentives to reveal the information if it allows one firm to gain sales by comparing itself to others (Milgrom and Roberts 1986). Of course, in other situations competitors may exploit the lack of consumer rationality.

- Berry, S. and P. Reiss (2004) "Empirical Models of Entry and Market Structure," in R. Porter and M. Armstrong, *Handbook of Industrial Organization*, Vol. 3, North Holland.
- Berto Villas-Boas, S. (2004) "Vertical Contracts Between Manufacturers and Retailers: Inference With Limited Data", University of California Berkeley working paper.
- Berry, S., J. Levinsohn, and A. Pakes (1995) "Automobile Prices in Market Equilibrium," *Econometrica*, 63:4, 841-89.
- Bussemeyer, Jerome R. and In Jae Myung (1992) "An adaptive approach to human decision making: Learning theory, decision theory, and human performance," *Journal of Experimental Psychology: General*, 121 (2), 177-94.
- Camerer, C. and Ho T-H (1994) "Violations of Betweenness Axiom and Nonlinearity in Probability," *Journal of Risk and Uncertainty*, 8, 167-196.
- Camerer, C. and T-H Ho (1999) "Experience-Weighted Attraction Learning in Normal Form Games," *Econometrica*, 67(4), 827-874.
- Camerer, C., T-H Ho, J-K Chong (2002) "A Cognitive Theory of One-Shot Games," *Quarterly Journal of Economics*, August 2004, 119(3), 861-898.
- Camerer, C., and R. Thaler (1995) "Ultimatums, Dictators, and Manners," *Journal of Economic Perspectives*, IX, 209-219.
- Che, H., Seetharaman, P.B. and K. Sudhir (2004) "Pricing Behavior in Markets With State-dependence in Demand," University of California at Berkeley working paper.
- Chintagunta, P., Dubé, J.P. and V. Singh (2003) "Balancing Profitability and Customer Welfare in a Supermarket Chain," *Quantitative Marketing and Economics*, 1, 111-147.
- Draganska, M., and D. Jain (2004) "Product Line Length as a Competitive Tool," *Journal of Economics and Management Strategy*, forthcoming.
- Erdem, T. and M. P. Keane (1996) "Decision-Making under Uncertainty: Capturing Dynamic Brand Choice Processes in Turbulent Consumer Goods Markets," *Marketing Science*, 15, 1-20.
- Erdem, T., S. Imai and M. P. Keane (2003), "Brand and Quantity Choice Dynamics under Price Uncertainty," *Quantitative Marketing and Economics*, 1, 5-64.
- Erdem, T., M. P. Keane, T. S. Öncü and J. Strebel (2005) "Learning about Computers: An Analysis of Information Search and Technology Choice," *Quantitative Marketing and Economics*, forthcoming.
- Fehr, E. and K. Schmidt (1999) "A Theory of Fairness, Competition, and Cooperation," *Quarterly Journal of Economics*, August, 817-868.

- Geweke, J. M. P. Keane (2001) *Computationally Intensive Methods for Integration in Econometrics. Handbook of Econometrics*, Vol. 5, J.J. Heckman and E. E. Learner (eds.), Elsevier Science.
- Gönül, F. and K. Srinivasan (1996) "Estimating the Impact of Consumer Expectations of Coupons on Purchase Behavior: A Dynamic Structural Model," *Marketing Science*, 15, 262-279.
- Grossman, S. J. (1981) "The Informational Role of Warranties and Private Disclosure about Product Quality," *Journal of Law & Economics*, 24(3), 461-83.
- Guerre, E., Perrigne, I. and Vuong, Q. (2000) "Optimal Nonparametric Estimation of First-Price Auctions," *Econometrica*, 68, 525-574.
- Hendel, I., and A. Nevo (2002) "Measuring the Implications of Sales and Consumer Stockpiling Behavior," Working Paper, UC Berkeley.
- Hotz, V.J. and Miller, R.A. (1993) "Conditional Choice Probabilities and the Estimation of Dynamic Models," *Review of Economic Studies*, 60, 497-529.
- Houser, D., M. Keane K. McCabe (2004) "Behavior in a Dynamic Decision Problem: An Analysis of Experimental Evidence Using a Bayesian Classification Algorithm," *Econometrica*, 72(3), 781-822.
- Jolls, Christine, Cass R. Sunstein and Richard Thaler (1998), "A Behavioral Approach to Law and Economics," *Stanford Law Review*, 50, 1471-1550.
- Kahneman, D., J. Knetsch, and R. Thaler (1986) "Fairness as a Constraint on Profit Seeking: Entitlements in the Market," *American Economic Review*, LXXVI, 728-741.
- Kahneman, D. and A. Tversky (1979) "Prospect Theory: An Analysis of Decision under Risk," *Econometrica*, 47, 263-292.
- Kivetz, R., O. Netzer and V. Srinivasan (2004) "Alternative Models for Capturing the Compromise Effect," *Journal of Marketing Research*, 41 (3), 237-157.
- Kruschke, John K. (1992), "ALCOVE: An exemplar-based connectionist model of category learning," *Psychological Review*, 99 (1), 22-44.
- Laibson, D. (1997) "Golden Eggs and Hyperbolic Discounting," *Quarterly Journal of Economics*, 62(2), 443-478.
- Lowenstein, G. and D. Prelec (1992) "Anomalies in Intertemporal Choice: Evidence and Interpretation," *Quarterly Journal of Economics*, 57, 573-98.
- Lucas, R. E. (1976): "Econometric Policy Evaluation: A Critique" in Karl Brunner and Allan H. Meltzer, eds., *The Phillips Curve and Labor Markets*, Carnegie-Rochester Conference Series on Public Policy, 1, 19-46.

- March J.G., (1996) "Learning to Be Risk Averse," *Psychological Review*, 103 309-319.
- McKelvey, R., and T. Palfrey (1995) "Quantal Response Equilibria for Normal-form Games," *Games and Economic Behavior*, VII, 6-38.
- Mehta, N., S. Rajiv and K. Srinivasan (2003) "Price Uncertainty and Consumer Search: A Structural Model of Consideration Set Formation," *Marketing Science*, 22(1), 58-84.
- Mehta, N., S. Rajiv and K. Srinivasan (2004) "Role of Forgetting in Memory-based Choice Decisions," *Quantitative Marketing and Economics*, 2(2), 107-140
- Melnikov, O. (2000) "Demand for Differentiated Durable Products: The Case of the US Computer Printer Market," Working Paper, Yale University.
- Meyer, Robert J., and Yong Shi (1995) "Intuitive Solutions to the Armed-Bandit Problem", *Management Science*.
- Milgrom, P. and J. Roberts (1986) "Relying on the Information of Interested Parties," *Rand Journal of Economics*, 17, 18-32.
- O'Donoghue, T., and M. Rabin (1999) "Doing it Now or Later," *American Economic Review*, 89(1), 103-124.
- Pakes, A., M. Ostrovsky, and S. Berry (2003) "Simple Estimators for the Parameters of Discrete Dynamic Games (with Entry/Exit Samples)," NBER Working Paper w10506.
- Parco, J., A. Rapoport and W. Amaldoss (2004), "Two-Stage Contests with Budget Constraints: An Experimental Study," Working Paper, Dept. of Management, United States Air Force Academy, Colorado Springs.
- Pesendorfer, M., and Schmidt-Dengler (2003) "Identification and Estimation of Dynamic Games," NBER Working Paper w9726.
- Petrin, A., and K. Train (2003) "Omitted Product Attributes in Discrete Choice Models," University of Chicago Working Paper.
- Prelec, D. (1998) "The Probability Weighting Function," *Econometrica*, 66(3), 497-527.
- Rabin, M. (1993) "Incorporating Fairness into Game Theory and Economics," *American Economic Review*, LXXXIII, 1281-1303.
- Reiss, P. (1996) "Empirical Models of Discrete Strategic Choice," *American Economic Review*, 86, 421-426.
- Reiss, P., and F. Wolak (2003) "Structural Econometric Models: Rationales and Examples from Industrial Organization", Stanford GSB working paper.

- Rust, J. (1994) "Structural Estimation of Markov Decision Processes," in R. Engle and D. McFadden *Handbook of Econometrics*, Vol. 4, Ch. 51, Elsevier, North Holland.
- Song, I., and P. Chintagunta (2003) "A Micromodel of New Product Adoption with Heterogeneous and Forward-Looking Consumers: Application to the Digital Camera Category," *Quantitative Marketing and Economics*, 1 (4), 371-407.
- Sudhir, K. (2001) "Structural Analysis of Competitive Pricing in the Presence of a Strategic Retailer," *Marketing Science*, Summer, 244-264.
- Sun, B., S. Neslin, and K. Srinivasan (2003) "Measuring the Impact of Promotions on Brand Switching Under Rational Consumer Behavior," *Journal of Marketing Research*, 40 (4), 389-405.
- Thaler, R. (1995) "Mental Accounting and Consumer Choice," *Marketing Science*, 4(3), 199-214.
- Tversky, A., and D. Kahneman (1992) "Cumulative Prospect Theory: An Analysis of Decision under Uncertainty," *Journal of Risk and Uncertainty*, 5, 297-323.
- Tversky, A., and I. Simonson (1993) "Context-Dependent Preferences," *Management Science*, 39 (10), 1179-1189.
- Villas-Boas, M., and Y. Zhao (2005) "Retailer, Manufacturers, and Individual Consumers: Modeling the Supply Side in the Ketchup Marketplace," *Journal of Marketing Research*, 42, 83-95.